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CORROSION IN THE AUSTRALIAN DEFENCE SCENE. 1. THE ARMY AND ANCI--ETC(U)
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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

MATERIALS RESEARCH LABORATORIES

MELBOURNE, VICTORIA

REPORT

MRL-R-752

CORROSION IN THE AUSTRALIAN DEFENCE SCENE

1. THE ARMY AND ANCILLARY EQUIPMENT FOR THE RAAF

Jeffrey J. Batten

Approved for Public Release

AUGUST, 1979

DEPARTMENT OF DEFENCE

MATERIALS RESEARCH LABORATORIES

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ABSTRACT

Although Australia purchases much of its advanced military equipment from other TTCP countries, there are differences between Australia and these countries with respect to usage and expected life of that equipment. These differences carry with them considerable corrosion penalties.

This paper describes case histories of some of the more recurrent types of corrosion problems. It is concluded that the choice of correct materials, techniques and design are essential to reduce the number of these problems. Further, the technology which would have prevented their occurrence was already in existence. Thus they mostly arose through lack of technology transfer from the corrosion scientist to the market place.

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POSTAL ADDRESS: Chief Superintendent, Materials Research Laboratories
P.O. Box 50, Ascot Vale, Victoria 3032, Australia

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16. ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):

Although Australia purchases much of its advanced military equipment from other TTCP countries, there are differences between Australia and these countries with respect to usage and expected life of that equipment. These differences carry with them considerable corrosion penalties.

This paper describes case histories of some of the more recurrent types of corrosion problems. It is concluded that the choice of correct materials, techniques and design are essential to reduce the number of these problems. Further, the technology which would have prevented their occurrence was already in existence. Thus they mostly arose through lack of technology transfer from the corrosion scientist to the market place.

SUMMARY

This paper was presented at the meeting of TTCP SUB-GROUP P, Technical Panel P1 (Metals) held in Melbourne in May 1979, its role being to contribute to Assignment Number 6: Corrosion Detection, Monitoring and Assessment.

Although Australia purchases much of its advanced military equipment from other TTCP countries, and thus there is a commonality of equipment, there are differences between Australia and the other countries within the TTCP framework with respect to the concepts of usage and expected life of military equipment. These differences carry with them considerable corrosion penalties.

This paper describes case histories of some of the more recurrent types of corrosion problems that are encountered. From this it is concluded that the choice of correct materials, techniques and design are essential to reduce the number of corrosion problems. It is also concluded that for most of the cases the technology which would have prevented the occurrence of the corrosion problems was already in existence. Thus they mostly arose through the lack of technology transfer from the corrosion scientist to the market place where that technology was required.

C O N T E N T S

CORROSION IN THE AUSTRALIAN DEFENCE SCENE

1. THE ARMY AND ANCILLARY EQUIPMENT FOR THE RAAF

1. THE NATURE OF THE PRESENT TTCP TASK

Sub-Group P of TTCP in 1975/76 assigned to their Technical Panel 1 (Metals) the task of reviewing current techniques for detecting and monitoring the onset and growth of surface corrosion in specific military systems, with a view to identifying opportunities for improving techniques and extending their applicability. The Technical Panel found it was unable to identify any basis for a collaborative programme on corrosion monitoring and because of the complexity of the subject referred the assignment back to the Sub-Group for endorsement of that opinion.

In 1977 Sub-Group P, conscious of the high cost of corrosion in defence maintenance, decreed that an additional dimension should be added to the assignment. To this end the scope was broadened and the task became "Corrosion Detection, Monitoring and Assessment", and the first step in this new assignment was to identify the particular types of corrosion failure in specific systems that carried the greatest economic penalties. Such information would enable attention to be concentrated on the development of techniques to monitor the most costly types of corrosion. The Panel considered, however, that it was not feasible or desirable to carry out analyses of the cost of corrosion damage and that the task would be tackled in the first instance by identifying primary areas of corrosion that cause concern, and at a later stage examining techniques for detection and monitoring.

For the reasons outlined above, the objective of the present task is to identify the primary areas of corrosion in military equipment where maintenance could benefit from the acquisition of more meaningful corrosion data. It is not intended to carry out a detailed analysis of the cost of this corrosion. Thus the present paper is a general appraisal of corrosion problems, current and potential, affecting Army and Air Force equipments. The paper was prepared for discussion at the 1979 meeting of TP1 held in Melbourne in May. A review of corrosion problems experienced by the Navy is the topic of a separate report.

2. THE SIGNIFICANCE OF CORROSION DAMAGE IN DEFENCE EQUIPMENT

Cost of corrosion is usually measured by money, however this approach overlooks the critical nature of corrosion damage in the military situation. In a war situation it is absolutely essential that defence equipment works correctly at all times, and failure to do so can have very serious consequences. Thus corrosion control is of vital importance to the Defence Forces because of the need for the easy maintainability, functionability, and combat readiness of military equipment, especially after prolonged periods of use, storage, or idleness.

Reliability of equipment is essential for the protection of the fighting soldier in the battlefield environment, and the consequences of failure can be catastrophic. In the military situation an essential element is the delivery of destructive energy to a target following its detection, location and identification before that target has a chance to do the same to you.

Thus although it is appreciated that corrosion control is expensive, failures due to corrosion damage can be even more so.

3. IDENTIFICATION OF PRIMARY AREAS OF CORROSION

In order to appreciate the significance of the origin of some of the corrosion problems, it is first necessary to define the Australian defence philosophy to equipment life.

3.1 Australian Defence Philosophy to Equipment Life

This philosophy aims at maximum reliability and lowest cost of ownership. To this end control of corrosion processes, both during storage and in use, is important for much of the cost of ownership results from deterioration of the constituent materials. This deterioration can be expensive to repair and can cause operational problems through unreliability or unavailability of the equipment.

Thus, in general, the Australian defence philosophy is to improve performance, reliability, and extend the safe service life of military equipment for as long as practicable. This concept centres around the problems of maintenance, detection and prevention of corrosion, and extension of both shelf and operational life of all forms of military equipment. In addition, many of the problems experienced in Australia are consequences of the use of (in general) overseas designed and manufactured equipment in the Australian environment.

3.2 Example of Control of Corrosion Processes During Storage: Preservation of Army Vehicles

Nature of the problem - Materials Research Laboratories (MRL) was requested to examine and comment on proposed preservation techniques applicable for storage periods of up to five years for the M-113 armoured personnel carriers and Leopard tanks.

Technique proposed - Naturally the preservation technique would depend on the geographic location of the storage area (hot/wet, hot/dry, etc), and whether or not the storage was to be under cover. With regard to this latter point, after inspection of the armoured personnel carriers we concluded that storage under roofed cover was absolutely essential. In this case, with the exception of steel brake discs, external metal surfaces would not require special treatment.

On the other hand, special treatment would be required on the metallic surfaces within the engine and transmission areas. The reason for this is that the corrosion-protection value of normal lubricating oils is dependent on film weight and that these oils will completely drain from vertical surfaces over a period of a few months. As a result bare steel surfaces are exposed to attack not only by oxygen and moisture, but also by acidic oxidation products formed either by oxidation of the oil or by combustion of the fuel.

The problem of drainage can sometimes be catered for by the use of thixotropic oils. However this use can be restricted when consideration is given to the blocking tendencies of any narrow oil galleries or other restrictions within the lubrication system. The most satisfactory method of resolving the problem of preventing corrosion of these internal passages is still to be determined.

Another approach is to incorporate in the lubricating oil suitable vapour corrosion inhibitors (V.C.I.'s). In this case protection is provided within engines into which this oil is introduced, even on surfaces to which the oil has no direct access. It is realised, however, that V.C.I.-containing oils can only be used with caution on mixed metal assemblies as the V.C.I.'s presently in use can be corrosive to some non-ferrous metals.

Another area that requires special attention are the brake wheel and master cylinders. One possible method of resolving the problem of their long term storage is to remove them from the vehicles and, after cleaning, to enclose them in sealed containers with a suitable V.C.I.

3.3 Case Histories of Corrosion Problems

This survey mainly revie[illegible] corrosion problems that have come to the Electrochemistry Group at MRL for solution. These problems have been classified as shown in Table 1, namely horizontally according to the adequacy of technology and/or its transfer, and vertically according to usage history or intended usage of the equipment.

The corrosion problems reviewed in Table 2 are mainly those that recurred and also those that carried the greatest economic penalties.

4. LESSONS LEARNT FROM CASE HISTORIES

4.1 Lack of Technology Transfer

Experience gained from a study of these case histories indicates that, in general, the technology was already available to have prevented most of these corrosion problems. Thus what is required is a more efficient transfer of that technology to those users who need it to cope with each stage of the history of the equipment, namely design, manufacture, storage, or in-service use. Unfortunately all too often the transfer sequence breaks down.

In general, person-to-person contact from the prime source of information to the actual person who needs that information is the only really effective means of communicating information. Thus there is a definite need for the corrosion scientist to leave his "ivory tower" and go to the market place where that technology is required.

To the above end, with our Navy some progress has been made in technology transfer at the user end of the spectrum through the formation of the Royal Australian Navy Corrosion Committee (RANCC). This committee consists of representatives from Naval Technical Services, the Navy dockyards, and corrosion scientists. However, this committee can have only little impact on the design stage of equipment purchased from overseas.

Within the very near future it is hoped to create a similar corrosion committee for the Royal Australian Army. In the distant future a RAAFCC may ultimately be formed. At that stage the scene will be set to form a Defence Force Corrosion Committee whose role will be to co-ordinate the activities of the three Service corrosion committees.

4.2 The Consequences of Using Overseas Designed Equipment

(a) Usually sophisticated items such as missiles, aircraft, electronic components and ordnance have to remain in service in Australia longer than the original design life. The long-term influence of corrosion is therefore of great concern.

(b) Problems are created which are associated with the lack of special expertise in some areas of the Australian Defence Industry and with the use of advanced materials.

(c) With overseas designed equipment such as advanced military systems, spares can be costly and sometimes available only with difficulty, and compositions of materials are often not revealed. Because of the long life expected in Australia, production of replacement parts in the overseas country may have ceased. Thus the capability for refurbishment in Australia is essential.

(d) Delays may be experienced due to the time required to transport spares to Australia.

(e) The transport of equipment by sea creates corrosion problems which may not occur in the countries of origin. Such equipment must be adequately protected against the marine environment during transit.

(f) Differences in raw materials can influence the performance of components.

(g) There is little scope for design modifications to cope with problems revealed under Australian service conditions.

4.3 The Consequences Arising from Australian Usage Conditions

(a) The Australian Defence attitude to equipment life, namely it is to be retained in service for very long periods, creates corrosion problems.

(b) Equipment must be capable of performing in hot/wet and hot/dry climatic conditions as well as in temperate conditions and in marine environments. Thus equipment needs to be designed to withstand these many different environments.

(c) Equipment must operate over vast distances for long periods and often remote from normal base servicing facilities. Thus reliability of equipment coupled with ease of maintenance is essential.

(d) The low usage rate of specialised military vehicles gives scope for the more insidious forms of corrosion.

(e) Storage of supplies, spare parts, ammunition, etc. over very long periods of peacetime raises many corrosion problems.

5. TECHNOLOGY TRANSFER, AUSTRALIA-TTCP COUNTRIES

Because Australia purchases most of its equipment from other TTCP countries much of this equipment is common to these countries. Further, ambient conditions of storage and use (providing tropical areas are excluded) which can lead to equipment deterioration, are similar between all the TTCP countries. Although Australia has different usage conditions (as indicated in Sections 4.2 and 4.3), because of the above similarities all TTCP countries must benefit from a cross-transfer of their experiences (i.e. their technology) with this equipment.

It is clear that the growth of knowledge between the various members of TTCP needs to be geared to the local progress, and that local technical competence within Australia is exceeded by that of some of the TTCP countries. For this reason, it is necessary to foster technology transfer by means of exchange of scientists and technicians between Australia and its major TTCP partners.

6. CONCLUSION

From the survey of case histories, it is apparent that most of the corrosion problems experienced in Australian defence equipments do not result so much from lack of background data or methods of controlling corrosion, as from lack of application of the existing technology. In only a very few problems was more research needed to reach a practical solution. The problems generally highlighted the need for designer awareness of corrosion problems; in fact most of the current problems have, to some degree, a design element which contributed more to failure than materials deficiencies do.

The philosophy behind corrosion control in general is acceptance of the fact that corrosion may be regarded as a design problem. On this basis, corrosion can be controlled to within acceptable limits by both the design engineer and the corrosion scientist achieving an improved appreciation of service corrosion conditions and then giving careful consideration to the selection of all materials, material protective finishes, geometry, etc. proposed for the manufacture of materiel at the design stage. Thus the onus for correct design rests with the design engineer and the corrosion scientist. To this end, the corrosion scientist has the responsibility of recognising corrosion-prone situations and originating correct remedial procedures. Management has the final responsibility for the application of adequate anti-corrosion measures. Therefore, they must be convinced of the long term economic advantages of these approaches.

The paper has considered activities relevant to the maintenance of operational service equipment. An indication of current capabilities, and their inadequacies, have been discussed and it is apparent that there is considerable scope for improvement. Such improvements in the key problem areas discussed would significantly assist in the efficient and reliable maintenance of service equipment.

Most of the countries associated with TTCP would recognise the importance of reducing the cost of ownership of military equipment. Some of the problems would be suitable for collaborative action, either by technology exchange or scientific investigation. Certainly Australia cannot hope to solve all defence corrosion problems by use of its resources alone, and this statement would be common to most TTCP countries. However, in joining with each other to pool resources towards solving key problems, it is most important that the best areas of opportunity and relevant objectives should be selected very carefully.

The role of each country in contributing to the joint venture needs to be considered in terms of the philosophies and capabilities of that country.

The examples quoted in this paper indicated that in most cases the technology was already available to have prevented most of these corrosion problems. Further, it would appear that there is little need for the application of corrosion monitoring to the types of corrosion problems discussed. In fact, our efforts would be better expended transferring anti-corrosion measures to the market place.

TABLE 1

CLASSIFICATION OF CORROSION PROBLEMS ACCORDING TO TECHNOLOGY AND ITS TRANSFER, AND USAGE HISTORY

Usage History or Intended Usage of Equipment	Adequate Technology		Inadequate Technology (C)
	Technology transfer inadequate to the designer and/or to the manufacturer (A)	Technology transfer inadequate to the user (B)	
In Long Term Storage (1)	(A1)	(B1)	(C1)
Seldom Used (2)	(A2)	(B2)	(C2)
Frequently Used (3)	(A3)	(B3)	(C3)

TABLE 2

SUMMARY OF CORROSION PROBLEMS GROUPED ACCORDING TO TECHNOLOGY AND ITS TRANSFER, AND USAGE HISTORY

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A1	Army	Zinc-plated steel fuze bodies of the PDM 48 Fuze	Moderate corrosion damage. 90,000 fuzes involved of value in excess of one million dollars.	Fuzes corroded after one year in storage. Required storage life was 20 years. Storage conditions moderate. Fuzes stored in wooden boxes lined with bituminous paper and components separated by cardboard.	Incorrect packaging technique. Corrosion may have been due to condensation of water vapour on the components in the partially sealed package or due to corrosive vapours emitted from the packaging materials.
A1	Army	Magnesium batteries used in back-pack radio	Major corrosion damage. Another lot of batteries of value about one million dollars to be ordered.	Batteries corroded after less than 12 months in storage. Required storage life was five years. Corrosion due to direct contact between depolariser particles and magnesium case.	Corrosion damage brought about by inadequate design of the interior components of the battery.
A1	Army	Armour piercing sabot round	Corrosion damage minor/moderate. Pilot batch of 300 affected.	Finger print marks on the completed magnesium sabot; this could lead to corrosion during the proposed long-term storage. Also the surface was powdery after the final surface pre-treatment step and this could lead to poor adhesion of the paint finish.	Insufficient care (handling) during manufacture and probable incorrect conditions for surface treatment.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A1, A2, and A3	Army	Class 16 air portable bridge	Moderate corrosion damage.	Corrosion of internal surfaces of deck box units and ramp units. For unused units in storage, patches of white powder associated with aluminium swarf. For used units (some in store) corrosion damage more extensive. Corrosion on most uncoated steel fittings.	Water seepage due to break down of sealing compound applied to rivet holes and internal fittings on assembly.
A1, A2, and A3	Army	Light floating bridge tactical raft	Corrosion damage moderate/major. Damage very significant as integrity of rivets is in doubt.	Have both pitting and galvanic corrosion. Main corrosion associated with rivets due to rivets and sheet metal not being compatible although both are aluminium alloys.	Pitting corrosion due to inappropriate use of an aluminium alloy containing copper. Later models used an alloy containing zinc - this is satisfactory providing surface coating in good condition. Galvanic corrosion due to design faults and the corrosive environment.
A1	Air Force	Corrosion of fusing conduits in Mark 82 bomb	Major corrosion damage. Many bombs affected.	Bombs manufactured and filled in 1969/70. Steel fusing conduits severely corroded although sealed during storage.	Corrosion probably due to contamination of the surface prior to painting.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A2	Army	Corrosion in landing craft LCM 6 in semi-storage conditions	Corrosion damage moderate. Expensive maintenance required.	Corrosion of hull and fittings: (a) Corrosion in the uncoated double bottom voids due to ingress of water by leakage around covers over access ports used for inspection purposes.	(a) Extremely limited accessibility prevented suitable surface preparation and coating application, thus it is a design fault. No provision made to suck the water out of these regions to reduce the extent of corrosion.
				(b) Well deck drain sump heavily corroded. Exterior surface unpainted.	(b) Corrosion due to lack of a heavy duty paint coating. Corrosion enhanced by the proximity of a large bilge suction valve of bronze by a bimetallic effect. Painting the valve exterior would diminish this effect.
				(c) Small plate covers over cable conduits severely corroded.	(c) Corrosion attributed to lack of accessibility (as in (a)) of their rear surfaces and lack of adequate drainage. Again a design problem.
				Corrosion of sea water system in the engine room: (d) Main corrosion is in the galvanised piping of the sea-water, bilge pumping and exhaust cooler systems.	(d) A corrosion resistant piping material for all sea water and engine room bilge services should have been used. Again a design fault.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A2	Air	Ejection seat components from Mirage aircraft	Corrosion damage moderate to major. Applicable to a number of aircraft particularly those stationed at Butterworth in Malaysia.	Corrosion within the bore of the escapement wheels. Although the main surfaces of the steel escapement wheels were cadmium plated, there was no coating within the bores. Thus bare steel was exposed.	Corrosion of the bore was due to exposure of the unprotected steel bore to a highly humid environment. Cadmium coating of the bore, followed by lubrication of the assemblies with a corrosion preventive oil or grease (PX type) would alleviate the problem.
A3	Army	Zinc-plated steel wave washers for the M 412 fuze	Major corrosion damage affecting complete batch imported from overseas.	During plating in Australia, blisters appeared in the zinc plating. Blisters arose because of inadequate removal of rust prior to plating.	Rusting arose because of inadequate surface protection during transit by ship from overseas.
A3	Army	Radio terminal set AN/MRL-127-F1	Major corrosion damage affecting about 100 sets valued at about five million dollars.	Lack of adhesion of the silver plate on both the cast and wrought aluminium components.	Corrosion damage of cast components due to corrosive plating solution trapped in surface porosity in the casting. These solutions subsequently caused the corrosion damage. With the wrought components damage attributed to inadequate surface preparation and inadequate coating thickness. Both problems attributed to faulty manufacturing technique.

<u>Note</u>: This is representative of a recurrent type of problem, namely one where corrosive liquids from protective surface treatments have not been completely removed from surface defects. These liquids subsequently caused the corrosion defect.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A3	Army	Field kitchen fuel tanks	Corrosion damage moderate. Twenty known cases, but many more are probable.	Internal surfaces of the bottom of the steel tanks corroded. Tanks had been nickel plated on the internal surfaces.	Thickness of plating insufficient to prevent corrosion due to ingress of moisture.
A3	Army	Medium girder bridge.	Corrosion damage moderate.	(a) Corrosion of cadmium-plated steel locking pins. (b) Abrasive damage to the paint, zinc coat and parent metal (aluminium alloy) during use and transport leads to general corrosion due to normal weathering.	(a) Inadequate cadmium plating thickness, also mechanical damage that is hard to avoid. (b) This damage due to normal handling would be difficult to avoid.
A3	Army	Radio set AN/GRC 125, matching unit antenna base MX 6707/VRC	Corrosion damage moderate to major. Many sets affected. Problem also experienced by the United States Army.	Severe internal corrosion. The equipment was used in a shipboard role, fitted to LARC MK5. The antenna base was fitted onto the deck with portion of the base protruding into the battery compartment.	Corrosion attributed to salt spray, ingress via faulty seals. Seals on switch and connectors not satisfactory because of cracking of the moulded mounting skirt thus allowing the moisture ingress. The proximity to the battery was not a contributing factor.
A3	Air Force	ALQ-94 low band aluminium heat exchanger assemblies from F111C aircraft.	Corrosion damage moderate. Several of these components affected.	Corrosion of areas associated with holes drilled through the component. These holes were drilled through slots that had been incorporated in the baseplate structure as part of the manufacturing process.	During processing these slots had filled with corrosive liquids used in chemical surface treatments. Thus fault is due to poor design and lack of appreciation that these solutions can be very corrosive.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the *Corrosion* Damage
A3	Air Force	Zinc-plated steel cartridge cases for the DEFA gun on Mirage aircraft	Corrosion damage minor to moderate. 210,000 cases affected and subsequently reclaimed.	Corrosion occurred on the bases of the cartridges after zinc plating.	Pits were formed in the bases during manufacture. Corrosive chemicals trapped in these pits during plating subsequently corroded the steel and the zinc plating.
A3	Air Force	Pneumatic retro ejector reservoirs from P3B Orion aircraft.	Corrosion damage moderate. All subject reservoirs in the RAAF's Orion fleet could be suspect. Thus could be a major problem.	Corrosion of the internal surfaces of the steel reservoirs taking place under phenolic resin internal coating. This type of corrosion is known as filiform corrosion.	During service the interior surfaces of these reservoirs would be perpetually wet due to condensation of water from the compressed air. Thus an inappropriate coating has been used for these *conditions* of service.
A3	Air Force	Electrically operated fire extinguisher cartridges for the Hercules C 130'E' aircraft.	Corrosion damage minor to major. Many components affected.	Components contained a bridge-wire spot-welded between a tin-coated steel centre pin and a similar annular ridge. In service this region would be embedded in the primer charge. Corrosion was exhibited on the steel substrate where the tin coating had been damaged during welding.	Poor electrical contact at weld sites associated with weld quality and pressure exerted by iron corrosion products. Severe corrosion with in-service cartridges suggested in-flight conditions were relevant to the failure, probably moisture ingress arising from inadequate closure disc sealing during manufacture. Milder corrosion of stored components probably due to moisture initially present in the charge.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A3	Air Force	Radar waveguides from the Orion P3-C aircraft.	Corrosion damage moderate. Several components affected.	Corrosion of brass corrugated flexible section with internal surfaces silver plated. Black, strongly alkaline deposit of silver oxide and sodium carbonate on surface. Beneath deposit, thickness of the silver plating considerably reduced.	The origin of the contamination is probably related to the silver plating process.
A3	Air Force	Cyrano radar waveguides from the Mirage aircraft.	Corrosion damage moderate. Several components affected.	Component made from a copper-beryllium alloy, internal surfaces silver plated. Internal surfaces heavily coated with grey/brown deposit toward one end, and green corrosion products toward other end.	Grey/brown deposit arose from silicone oil and silica gel. Green deposit due to RF arcing leading to thermal degradation of PTFE, resulting in fluoride corrosion products of the copper substrate through pin-holes in the silver coating. Arcing also results in nitrate corrosion products of the copper substrate, due to nitrogen being ionised and oxidised by the arcing. Cure is to reduce arcing, and eliminate the PTFE.
A3	Air Force	Radar duplexer AF/FPN-801.	Corrosion damage moderate.	Pitting corrosion on cast aluminium (98%Al) duplexer body, more general corrosion on the Cu-3% Be alloy spring contact strip.	Corrosion products from both components contained nitrates. Nitrates produced by arcing (see above). Solution is to reduce arcing and prevent water ingress.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
A3	Air Force	Radar transmitter cooling system.	Corrosion damage moderate.	Corrosion of the aluminium alloy components of the heat exchanger in various transformer tanks. Other metals present in the system include copper, stainless steel, brass and cast iron.	Corrosion of the aluminium components arose because of the bimetallic effect of the large amount of copper. The aluminium alloy heat exchangers should be replaced with ones made of copper.
B1	Air Force	Corrosion in F111C pylon tanks.	Corrosion damage moderate. Many tanks involved.	White aluminium corrosion products detected in tanks during storage. Tanks stored in the open with direct exposure to the sun. Large temperature drop at night has prompted ingress of water vapour (with subsequent condensation).	Incorrect storage resulted in general attack and localised severe pitting by water condensate. Long term protection afforded by sealing the tanks and pressurising with dry nitrogen.
B2	Army	Fuel tanks in armoured personnel carriers.	Corrosion damage major. Many fuel tanks could be affected.	Leakage of diesel fuel from holes in the bottom of the aluminium fuel tanks.	Fungal growth mats on the bottom of the fuel tanks, in the presence of water, caused severe random pitting. The intensity of the pitting varied from mild to severe, and in some cases the tanks were perforated.
B2	Army	Failure of brakes on tank transporters and 2.5 and 5 ton Army trucks.	Corrosion damage major. Several vehicles affected.	Failures due to seizure of the steel pistons of the brakes to the cast iron cylinder walls and/or corrosion of the cylinder thereby permitting leakage of the brake fluid. Both the master and wheel brake cylinders were affected.	Failures associated with ingress of moisture, the main contributor probably being washing by high-pressure hosing. Other contributing factors were "semi-storage" conditions with direct impingement by sun and rain, and also the use of hygroscopic brake fluid.

TABLE 2

(Continued)

Category	Service	Type of Items Affected by Corrosion	Magnitude of the Problem	Details of the Problem	Factors that Contributed to the Corrosion Damage
B3	Army	Cast magnesium battery cover for radio set PRC-F1.	Corrosion damage major.	Severe localised corrosion of the magnesium battery cover after use in a tropical environment. Magnesium surface coated with an organic protective coating.	Corroded zones corresponded with deep scratches and removal of protective coating; this attack inevitable on bare magnesium alloy in any moist environment. Service conditions too severe for organic protective coating. Users warned to be more careful.
C3	Army, Navy and Air Force	Water-cooling systems in ships, vehicles and plant.	Corrosion damage major and problem extensive.	Many corrosion problems in these systems.	Our technology is inadequate. There are many inhibitors and inhibitor combinations for water-cooling systems, but one with more universal application is required.

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